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Pilot Performance: Round Dial and Vertical Tape Altimeters

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Abstract

This paper addresses pilot performance with regards to a glass cockpit and an analog cockpit. Specifically, it looks at pilots' abilities to hold altitude with a vertical tape and round dial altimeters. Past research has concluded that a vertical tape altimeter has a more accurate altitude read out, but trends are easier to detect with the analog altimeter. This study looked at 24 participants who were split into three groups of eight. One group had no flight experience, one group had flight experience with only an analog cockpit, and one group had flight experience with only a glass cockpit. Participants filled out surveys that asked about their preference of altimeters, and with which altimeter they believed they achieved their best performance. Overall, the results showed that altitude was held better with a round dial altimeter even though the vertical tape altimeter was preferred.

Research Problem and Question

With the introduction of glass cockpits in not only commercial aviation, but also general aviation, pilots are now flying equipment with different presentations of information critical to the flight. The traditional cockpit has six main instruments: airspeed indicator, attitude indicator, altimeter, turn coordinator, heading indicator, and vertical speed indicator. Most airplanes have these instruments arranged in a specific pattern. A glass panel, such as the Garmin 1000, has the same instruments in the same pattern as the analog cockpit, but some information, like altitude and airspeed, is presented differently. Many glass cockpits utilize a vertical tape to represent altitude and airspeed versus the traditional round dial. Pilots who are accustomed to the traditional instrument panel have difficulty accurately interpreting the vertical tape because they

reference known round dial hand positions (Etherington & Gordon, 2004). The two questions that this paper will investigate are:

1) Can a pilot hold altitude more accurately with an analog altimeter or a vertical tape altimeter?

2) Does the pilot have a preference between the analog altimeter and the vertical tape altimeter?

Literature Review

Throughout the development of airplanes, cockpits have become increasingly advanced. The first cockpits had little to no instrumentation, and have progressed over the years to include analog instrumentation relying on the electrical, vacuum, and pitot static systems of the airplane (see Figure 1). As technology has advanced and the airspace has become more crowded, it has been a challenge to effectively utilize the limited space in an airplane cockpit. Starting in the 1970s, airplanes were equipped with newly developed electronic flight displays or glass cockpits (Curtis et al., 2010). Glass cockpits did not become common in general aviation aircraft until recently.

Figure 1: Standard Analog Cessna 172 Cockpit. From Left to Right Top: Airspeed, Attitude Indicator, Altimeter, NAV 1. From Left to Right Bottom: Turn Coordinator, Heading Indicator, Vertical Speed Indicator. Source: http://stoenworks.com/

Glass cockpits for general aviation aircraft started development in the 1980s and 1990s (see Figure 2). The first glass cockpits were installed in experimental and amateur built aircraft. In 2003, Cirrus was the first to start selling aircraft with electronic displays. Most of these displays incorporated a Primary Flight Display (PFD) and a Multi- Function Display (MFD).

The PFD during normal operation displays the attitude indicator, heading indicator, turn coordinator, airspeed indicator, altimeter and vertical speed indicator. The MFD during normal operation displays the map and engine instruments. The MFD also has the ability to cycle through multiple pages and display the preferred information to the pilot. Now most of the general aviation aircraft being produced come with a glass cockpit (NTSB, 2010).

Figure 2: This is a Cessna 172 equipped with a Garmin 1000. The PFD on the left has the attitude indictor with slip indicator as the background. On the bottom is the Heading Indicator with rate of turn indicator and NAV 1, NAV 2, and GPS navigation. One the left is the Airspeed Tape and on the right is the Altimeter Tape with Vertical Speed. The MFD is on the right. Source: theflightschool.com

With the new glass cockpit, information could be compactly displayed which allowed for more use of the limited space of a cockpit. Glass cockpit displays allowed the pilot to navigate through different pages, and this led to even more information being available to pilots on the flight deck (Curtis et al., 2010). The new displays of the standard six instruments are visually similar with regards to the heading indicator and the attitude indicator, but the airspeed indicator, altimeter, vertical speed indicator and turn coordinator differ greatly.

One of the most noticeable changes to the glass cockpit with respect to the primary instruments is the airspeed indicator and the altimeter. Once round dial instruments with hands, they are both now vertical tapes. The main disadvantage to the vertical tape is that it is more difficult to detect trends (Zhang et al., 2002). According Advisory Circular 25-11A which discusses electronic flight deck displays, “scales, dials and tapes with fixed and/ or moving pointers have been shown to effectively improve flight crew interpretation of numeric data.”

(FAA, 2007, p. 42) The vertical tape also gives a numeric read out of altitude which can be read easier than a hand on the round dial altimeter, but can be distracting due to the constant change of the numbers. Also, movement of the hands on a round dial altimeter is easier to detect than the scrolling of the vertical tape. In addition, pilots that are accustomed to the round dial altimeter, reference specific positions of the hands. For example, the 12 o'clock position indicates level at 3000, 4000, 5000 feet, etc. and the 6 o'clock position indicates level at 3500, 4500, 5500 feet, etc. This allows pilots to easily notice an altitude deviation in their peripheral vision (Etherington & Gordon, 2004).

Pilots may have difficulty detecting aircraft state because they do not fully understand the avionics, and there can be a "mismatch between the actual behavior of the avionics and the pilot's expectations" (Feary et al., 1998, p. 4). Pilots' difficulty with the new vertical tape could be the result of lack of adequate training. In a study done on human-centered visualization, three types of altimeters were compared based on function, user, task, and representational analysis. The function of the altimeter is to provide altitude information during different stages of flight. The user of the altimeter is the pilot; therefore, the altimeter must give information effectively to the pilot especially during stages of flight that are high workload. The task analysis looked at ability to read the number, perceiving motion and position, and capturing and maintaining altitude. The representation varies with each altimeter. The analog altimeter has three hands used to indicate altitude, the digital altimeter has a digital read out of altitude in addition to an analog component with hands, and the vertical tape altimeter has the digital readout and a scrolling tape (Zhang et al., 2002).

From the task analysis, the analog altimeter proved to be good for maintaining altitude, moderate at capturing altitude and perceiving position and motion, and poor at reading a number.

The digital altimeter was good for maintaining altitude, moderate for capturing and perceiving position, and good at reading the number. The vertical tape altimeter was good for perceiving motion and capturing and maintaining altitude, and moderate at perceiving position and reading a number.

From this information it is clear that the vertical tape is more accurate for the parameters measured. The tape combined with the digital number is the most effective for determining altitude. It also argues that a good visual representation will change with user preference (Zhang et al., 2002). This could account for why pilots who are accustomed to the round dial altimeter reference certain hand positions, and therefore, prefer the round dial altimeter.

Like previous studies, this study looks at two different types of altimeters, but also, looks at how prior experience with either type of altimeter or altimeter preference has an effect on performance.

Methodology

Participants

The participants in this study were 24 individuals selected from three different groups. The first group consisted of participants with no flight experience in airplanes or simulators. The second group consisted of participants with flight experience in airplanes with round dial altimeters. The third group consisted of participants with flight experience in airplanes with vertical tape altimeters.

Measures

Microsoft Flight Simulator Gold Edition for PC was used for this study. The two simulated airplanes were a Cessna 172 with a traditional analog cockpit and a Cessna 172 with a glass cockpit, specifically the Garmin 1000.

Procedures

Participants started with an explanation of the analog cockpit, followed by a one minute practice session. After they were accustomed to the panel, they flew straight and level for one minute and thirty seconds at 1600 feet, the default starting altitude for Microsoft Flight Simulator. Next they climbed to 2600 feet, and leveled off for one minute and thirty seconds. This was followed by a descent back to 1600 feet, and level off for one minute and thirty seconds. An identical practice session and flight sequence was repeated with the glass cockpit. Four of the participants from each group began with the analog cockpit and four from each group began with the glass cockpit.

The researcher recorded altitude deviations during the three straight and level flight sequences. The dependent variable was altitude. The independent variables were the analog cockpit or Garmin 1000 cockpit, and the type of flight experience.

A survey (See Appendix) regarding which cockpit the participants preferred and which cockpit the participants believed they achieved their best performance was given following the completion of the simulator flight. The researcher compared the participants' survey results to the performance results to determine if there was a relationship between their performance and cockpit preference.

Results and Discussion

The data collected from this study showed that on average altitude was held more accurately with a round dial altimeter (see Table 1). However, if each participant is considered individually the performance results varied, with some performing better with glass. For the group of participants with no experience, altitude was held on average 14.4 feet from altitude with a round dial altimeter and 27.5 feet from altitude with a vertical tape altimeter. This group yielded the greatest difference between the two altimeters. For the group of participants with round dial experience, altitude was held on average 11.7 feet from altitude with a round dial altimeter, and 14.3 feet from altitude with a vertical tape altimeter. For the group of participants with vertical tape altimeter experience, altitude was held on average 22.9 feet from altitude with a round dial altimeter, and 33.9 feet from altitude with a vertical tape altimeter. The vertical tape only participants performed worse than the other groups. This study does not provide a rationale for these surprising results. If each participant is looked at individually, some performed better with the vertical tape altimeter. The group of participants who had no experience and the group of participants who had only vertical tape experience both had six of the eight perform better with the round dial altimeter. The round dial experience group had four of the eight perform better with the round dial altimeter, and the other four perform better with the vertical tape altimeter.

According to the survey results, most participants preferred the vertical tape altimeter and believed that they performed better with the vertical tape altimeter (see Table 1). Some of the attached comments from the survey that could explain this include that the vertical tape altimeter is easier and clearer to read than the round dial altimeter. Also, most participants ended up utilizing the vertical speed indicator to help them hold altitude. Participants commented that

with the glass cockpit the vertical speed indicator is right next to the vertical tape altimeter, as opposed to a completely separate instrument in the analog cockpit with the round dial altimeter.

Table 1: Results

	No Flight Experience	Round Dial Experience	Vertical Tape Experience
Analog Results (deviation in feet)	14.4	11.8	22.9
Vertical Tape Results (deviation in feet)	27.5	14.3	33.9
Preference	7 Vertical Tape	6 Vertical Tape	6 Vertical Tape
	1 Round Dial	2 Round Dial	2 Round Dial
Performance	5 Vertical Tape	5 Vertical Tape	6 Vertical Tape
	3 Round Dial	3 Round Dial	2 Round Dial

Participants that preferred the round dial altimeter commented that it was easier to detect trends and less distracting because there were no distracting numerical readouts due to the number constantly changing. With the vertical tape altimeter 20 feet low would read 1580 or 2580, and cause the participant to react too drastically thinking the altitude deviation was greater than it actually was. With the round dial altimeter 20 feet low will not visually appear to be that far from 1600 or 2600 resulting in a less drastic reaction.

This limited study indicates that altitude was held more accurately with a round dial altimeter and that altimeter preference does not always assure best performance when holding altitude. The study was done with 24 participants, 8 in each group, and the collected data did not show a large difference between the two types of altimeters. A future study with more participants may provide more conclusive data. Also, other instruments could be tested such as the airspeed indicator, which is similar with round dial and vertical tape versions. The use of

Microsoft Flight Simulator had its advantages such as its mobility because it was on a laptop, but an actual flight simulator or flight training device would be more realistic.

If conclusive data shows that altitude is held more accurately with a round dial altimeter it could be beneficial to consider having the option of a round dial representation on a glass display instead of the current vertical tape display.

Conclusions

The new generation of glass cockpits has led to a new area to be examined by human factors analysts. With new developments in technology and many differing cockpits, it is important to determine pilot performance with this new technology. Overall, preference tends to be for the glass cockpit with the vertical tape altimeter, but this study suggests that performance is better with the analog cockpit with the round dial altimeter. Another study could be done to look at the effect on pilots of switching between an analog and glass cockpit. With advances in technology constantly changing the cockpit, further research should be done regarding its effect on pilot performance and design of more ergonomic cockpits.

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Appendix: Survey

Initial Survey

Have you ever flown an airplane?

Yes No

If yes, what type of cockpit do you have experience with?

Round Dial Vertical Tape

Have you ever used Microsoft Flight Simulator?

Yes No

Post Survey

Which panel did you prefer?

Round Dial Vertical Tape

Which panel do you feel you held altitude most accurately with?

Round Dial Vertical Tape

Other Comments: